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Screening Your Network to Improve Roadway Safety Performance – Getting Started




Network screening is a crucial step in the safety management process that identifies locations for potential safety investment according to their potential for future crashes. The potential for future crashes can be either directly based on the spot-specific crash history or on other factors that have potential to contribute to crashes, such as roadway factors and traffic characteristics.

WHAT IS NETWORK SCREENING?

Network screening is a method that objectively considers crash history, roadway factors, and traffic characteristics that may contribute to future crashes and helps agencies identify and prioritize locations for potential safety investment. The process includes the following five steps:

1. Establish a focus.
2. Identify the types of sites or facilities to be screened.
3. Select performance measures.
4. Choose a screening method.
5. Screen and evaluate results.

Network screening provides solid documentation and justification for prioritizing safety needs.

Agencies can screen their networks through routine business practices by collecting and analyzing crash, roadway, and traffic volume data. Several guides can assist agencies with the screening process, including FHWA's *Systemic Safety Project Selection Tool*,[1] AASHTO's *Highway Safety Manual* (HSM),[2] and FHWA's *Improving Safety on Rural Local and Tribal Roads — Safety Toolkit*.[3]

NETWORK SCREENING IN 5 EASY STEPS

Although many network screening methods exist, the example below outlines a step-by-step "quick start" approach that almost every agency can use to screen its jurisdiction's network for locations for potential safety investment. To get started with systemic safety analysis, see the companion guide: *Quick Start Guide to Systemic Safety Analysis*.[4]

Employing traditional network screening with **systemic safety analysis** can be an agency's first step toward a **comprehensive safety management program.**

Example: *In "Springfield, USA," a city of 30,000 people, the public works department experiences a high number of annual severe intersection crashes and wants to identify and prioritize potential safety investment locations. Springfield is a community hub centrally located in a mostly rural area. The city is host to many of the area's employment opportunities, shopping centers, restaurants, and other entertainment venues.*

1 Federal Highway Administration. *Systemic Safety Project Selection Tool*. FHWA-SA-13-019. 2013. Washington, D.C. Accessible at: https://safety.fhwa.dot.gov/systemic/fhwasa13019/sspst.pdf.
2 American Association of State Highway and Transportation Officials. *Highway Safety Manual*. 2010.
3 Federal Highway Administration. *Improving Safety on Rural, Local, and Tribal Roads – Safety Toolkit*, "Step 4. Diagnose Site Crash Conditions and Identify Countermeasures." FHWA-SA-14-072. 2014. Washington, DC. Available at: https://safety.fhwa.dot.gov/local_rural/training/fhwasa14072.
4 Federal Highway Administration. *Quick Start Guide to Systemic Safety Analysis*. FHWA-SA-17-009. 2013. Washington, D.C.

STEP 1 ESTABLISH A FOCUS

Identify sites with the potential to reduce future crash frequency or severity and focus on the most prevalent crash types.

The city's public works department operates and maintains 38 traffic signals. Agency staff know that angle crashes at signalized intersections have an increased potential for resulting in severe injuries or fatalities. They want to identify intersections with more severe angle crashes than expected.

The agency decides that focusing on angle crashes at signalized intersections will assist it in effectively reducing overall severe injuries and fatalities.

STEP 2 IDENTIFY THE TYPES OF SITES/FACILITIES TO BE SCREENED

Select a subset of roads or sites on which to focus improvements, such as all two-way, stop-controlled intersections or urban flat, four-legged intersections.

The city's 38 signalized intersections have the following characteristics. Grouping the intersections based on these characteristics forms reference populations.

- *Seventeen signals are classified as being located on arterials, 8 are on major collectors, and 13 are on minor collectors.*
- *Thirty-two signals are at four-legged intersections and 6 are at three-legged intersections.*
- *Ten signalized intersections have more than 20,000 Total Entering Vehicles (TEV) per day, 18 have between 10,000 and 19,999 TEV per day, and 10 have less than 9,999 TEV per day.*

Reference Population	Intersection ID	Number of Through Lanes	Total Crashes	Severe Angle Crashes
Three-Legged Intersections	3	1	22	9
	5	1	20	8
	18	2	37	12
	22	2	32	5
Four-Legged Intersections	2	1	29	6
	7	1	24	7
	8	1	17	7
	11	2	30	5
	16	2	28	13
	29	2	23	9

While screening a network allows agencies to screen hundreds of locations at once, we will assume the agency narrows its focus to 10 high-volume intersections for simplicity. The agency chose "number of approaches" as the reference population since the variation of intersection geometry within each is minimal compared to other grouping options. Four of these intersections are three-legged and six are four-legged. The staff enters the pertinent crash data for each intersection.

The agency separates the intersections into two reference populations: (1) three-legged intersections, and (2) four-legged intersections.

STEP 3 SELECT PERFORMANCE MEASURES

Specify one or more performance measures to evaluate one or more sites from Step 2. Performance measures could include more traditional methods such as crash frequency and severity or more advanced methods, which involve more detailed analysis and produce more reliable outputs compared to the traditional methods. The HSM outlines several advanced analysis methods that rely on crash data:

- Expected average crash frequency with empirical Bayes adjustment.
- Excess expected average crash frequency with empirical Bayes adjustment.
- Probability of specific crash types exceeding threshold proportion.

While the agency can proceed with just one of these analysis methods for this step, using multiple performance measures to evaluate each site can improve the level of confidence in the results during network screening.

The agency selects a more reliable performance measure and makes use of currently available data (i.e., probability of specific crash types exceeding threshold proportion) to evaluate each intersection's safety performance.

The *probability of specific crash types exceeding threshold proportion* method, as noted in the HSM (p. 4-12), prioritizes the sites based on the probability that the long-term predicted proportion is greater than the threshold proportion identified for each crash type, showing whether the location is performing worse than expected. This performance measure is not affected by regression-to-the-mean bias, and the only data needed to apply this method is **crash type and location data**. The agency executed the following calculations and obtained the result in approximately 15 minutes.

1) *Agency personnel calculate the observed proportions for each intersection.*

Example:
(HSM Equation 4-18)

$$\text{Observed proportion at Intersection 3} = \frac{\text{Number of observed target crashes at Intersection 3}}{\text{Total number of crashes at Intersection 3}} = \frac{9}{22} = 0.41$$

2) *They estimate a threshold proportion for each reference population.*

Example:
(HSM Equation 4-19)

$$\text{Threshold Proportion} = \frac{\text{Sum of observed severe angle crash frequency within the population}}{\text{Sum of total observed crash frequency within the population}}$$

$$= \frac{9 + 8 + 12 + 5}{22 + 20 + 37 + 32} = \frac{34}{111} = 0.306 \text{ for three-leg intersections}$$

3) *Then they calculate sample variance for each reference population following the equation below.*

Example:
(HSM Equation 4-20)

$$Var(N) = \left(\frac{1}{n_{sites}-1}\right) \times \left(\sum_{i=1}^{n}\left[\frac{N^2_{observed,i} - N_{observed,i}}{N^2_{observed,i(total)} - N_{observed,i(total)}}\right] - \left[\frac{1}{n_{sites}}\right] \times \left[\sum_{i=1}^{n}\frac{N_{observed,i}}{N_{observed,i(total)}}\right]^2\right)$$

Where: n_{sites} = *Total number of sites being analyzed*

$N_{observed,i}$ = *Observed severe angle crashes for a site i*

$N_{observed,i}$ *(total)* = *Total number of crashes for a site i*

Example:
For Three-Legged Intersections

$n_{sites} = 4$

$$\sum_{i=1}^{n}\left[\frac{N^2_{observed,i} - N_{observed,i}}{N^2_{observed,i(total)} - N_{observed,i(total)}}\right] = \left[\frac{9^2 - 9}{22^2 - 22}\right] + \left[\frac{8^2 - 8}{20^2 - 20}\right] + \left[\frac{12^2 - 12}{37^2 - 37}\right] + \left[\frac{5^2 - 5}{32^2 - 32}\right]$$

$$= 0.156 + 0.147 + 0.099 + 0.020 = 0.422$$

$$\sum_{i=1}^{n}\frac{N_{observed,i}}{N_{observed,i(total)}} = \frac{9}{22} + \frac{8}{20} + \frac{12}{37} + \frac{5}{32} = 0.409 + 0.400 + 0.324 + 0.156 = 1.289$$

$$Var(\text{Three-Legged Intersections}) = \left(\frac{1}{4-1}\right) \times \left(0.422 - \left[\frac{1}{4}\right] \times \left[1.289\right]^2\right) = 0.002$$

4) *They calculate mean proportion of target crash types and alpha and beta parameters, which will be used in the next step to calculate probability.*

(HSM Equation 4-22)

$$\alpha = \frac{\overline{p_i^*}^2 - \overline{p_i^*}^3 - s^2\,(\overline{p_i^*})}{Var\ (N)}$$

Note: For higher accuracy, use a calculation software like Microsoft Excel. Ensure that all decimal places are carried through. Rounding to the first or second decimal place during calculations can result in significantly different final values.

(HSM Equation 4-23)

$$\beta = \frac{\alpha}{\overline{p_i^*}} - \alpha$$

Where Var(N) = Variance (equivalent to the square of the standard deviations, s^2)

$\overline{p_i^*}$ = *Mean proportion of target crash types.*

Example:

$$\alpha \text{ (Three-Legged Intersections)} = \frac{0.306^2 - 0.306^3 - 0.002*0.306}{0.002} = 32.19$$

$$\beta \text{ (Three-Legged Intersections)} = \frac{32.19}{0.306} - 32.19 = 73.00$$

5) *They calculate the probability for each site. In an Excel spreadsheet, the agency staff inputs the below equation using the "BETADIST" function of Excel.*

(HSM Equation 4-24) *Probability of Severe Angle Crashes Exceeding Threshold Population*

= 1– betadist (Threshold Proportion, α + Observed Severe Angle Crashes, β

+ Total Number of Crashes – Observed Severe Angle Crashes)

Reference Population	Intersection ID	Total Crashes	Severe Angle Crashes	Observed Proportion	Threshold Proportion	Sample Variance	α	β	Probability
Three-Legged Intersections	3	22	9	0.41	0.31	0.0022	28.99	65.66	67%
	5	20	8	0.40					64%
	18	37	12	0.32					54%
	22	32	5	0.16					17%
Four-Legged Intersections	2	29	6	0.21	0.31	0.0033	19.79	43.80	24%
	7	24	7	0.29					45%
	8	17	7	0.41					65%
	11	30	5	0.17					16%
	16	28	13	0.46					82%
	29	23	9	0.39					66%

For each intersection, the probability column shows the probability of exceeding the threshold number of severe angle crashes for its respective reference population. For example, there is a 67 percent chance that the long-term expected proportion of severe angle crashes at Intersection 3 is actually greater than the long-term expected proportion for three-legged intersections.[5]

HINT!

Network screening software can simplify these procedures. For further information on available network screening tools, see FHWA's Roadway Safety Data Program (RSDP) Toolbox.[5]

[5] Federal Highway Administration. Road Safety Data Program. Available at: https://safety.fhwa.dot.gov/rsdp/toolbox-tool.aspx?pt=3.

STEP 4 CHOOSE A SCREENING METHOD

Three screening methods exist: sliding window, peak searching, and simple ranking methods. Each requires a differing range of analysis, from most to least complex, respectively.

After calculating the performance measures for the reference populations, the agency looks for the most suitable method to compare the numerical results. Only simple ranking is applicable for screening discrete nodes, such as intersections.

The agency chooses the simple ranking screening method to evaluate the intersections.

STEP 5 SCREEN AND EVALUATE RESULTS

Use the completed evaluation for all sites to compare, rank, and prioritize sites for potential improvements.

To screen the network, the agency ranks the intersections based on the probability of the target crash types (e.g., severe angle crashes) exceeding the threshold.

Example Results: Intersection Rankings

Rank	Intersection ID	Probability (%)
1	16	82
2	3	67
3	29	66
4	8	65
5	5	64
6	18	54
7	7	45
8	2	24
9	22	17
10	11	16

CONCLUSION

Following these five steps, Springfield Public Works Department identified intersections with the highest proportion of severe crashes among intersections with similar features. Thus, the network screening process objectively provides a list of locations where investing in improvements is likely to return the greatest benefit.

Network screening is just a starting point for further investigation. The next step is for the agency to review locations and identify appropriate countermeasures. For some locations on this list, a cost-effective solution may not exist.

The agency decides to prioritize the top five intersections for further investigation.

The data and analytical methods each agency selects to screen its network should be based on available resources and technical expertise. More comprehensive data can help practitioners to make better decisions, but lack of data should not preclude an agency from screening its network. Agencies should start with the existing resources, data, and expertise at their disposal. They can then progressively shift to more advanced network screening methods as more and better quality data becomes available. Agencies can also incorporate a systemic component to address locations with roadway factors and traffic characteristics similar to those with a history of severe crashes.

If Springfield had more comprehensive data, personnel could input other roadway factors in addition to the crash data to incorporate a systemic approach.

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